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PARTICLE BINDING COMPOSITIONS AND METHODS OF MAKING AND USING SUCH COMPOSITIONS

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PARTICLE BINDING COMPOSITIONS AND METHODS OF MAKING AND USING SUCH COMPOSITIONS

BACKGROUND OF THE INVENTION

1. The Field of the Invention

[0001] The invention is in the field of particle binding compositions useful in soil remediation, particularly those useful in binding soil or other particles in order to inhibit dust formation and erosion. The invention also relates to the manufacture and use of such compositions.

2. The Relevant Technology

[0002] Denuding of soil can result from various natural and man-made forces, examples of which include forest fires, bush fires, land slides, avalanches, and grading of land (*e.g.*, during the building of roads, bridges, buildings, and other man-made structures). Soil that is devoid of vegetation is vulnerable to erosion, which can be caused by wind and/or water. Erosion can result in long-term ecological damage and can pose a risk to wildlife and humans.

[0003] In addition, dirt roads, trails and paths intended for walking or vehicle use can become unstable unless the surface remains well compacted and with a relatively even grade.

[0004] In the case of denuded land, one strategy is to plant shrubbery or broadcast plant seeds that can quickly germinate in order to provide a root system that better stabilizes the soil. In addition, plants can also provide a barrier from wind and water, help

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maintain soil moisture, add organic matter to the soil, and provide food and shelter for animals, insects, microorganisms, and other life forms.

[0005] Sometimes, however, simply revegetating land by dropping seeds on denuded land is not effective, especially where the soil is quickly eroded by wind and water before the plants have germinated and become well established, or where the soil is simply too dry to cause seeds to germinate or support newly germinated plants. In some cases, plant matter (such as straw or mulch) is placed on the soil surface in an effort to stabilize soil and/or aid in moisture retention and seed germination. This strategy, though helpful in some cases, is not very effective in stabilizing dry soil from the effects of wind or sudden rain storms since the plant material is generally only loosely placed onto the soil surface. Without intimate mixing of the plant material with the soil being treated, there is little or no mechanical affinity of the soil for the plant material.

[0006] Surfaces of dirt roads have been stabilized by the application of chemicals such as tar or oil. While effective in preventing soil erosion, such strategies can cause unsightly scarring of the soil surface and long-term sterility of the underlying soil.

[0007] In view of the foregoing, there is therefore an ongoing need to develop improved compositions and methods that can be employed in order to bind and stabilize soil and other particles in order to, *e.g.*, prevent erosion, facilitate revegetation of soil, and/or provide a more stable soil surface.

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SUMMARY OF THE INVENTION

[0008] The present invention relates to particle binding compositions that can be applied to soil or other particles in order to stabilize them. In one aspect of the invention, particle binding compositions according to the invention can be applied to soil in order to bind the soil particles together so as to reduce wind and/or water erosion. In some cases, the compositions can assist in the vegetation or revegetation of denuded land.

[0009] The particle binding compositions according to the invention comprise water, an endosperm, an iron compound, a strong base, and a pH adjustor. A precursor composition comprising the non-aqueous components may be included in one or more initially separate parts that are mixed together in the presence of water in a desired mixing sequence.

[0010] The endosperm comprises the carbohydrate and protein portions of grains, seeds, or tubers. Examples of endosperm sources that may be used in the particle binding compositions of the invention include, but are not limited to, cereal grains (*e.g.*, wheat, rice and corn), other seeds (*e.g.*, soy beans), and tubers (*e.g.*, potatoes). The "endosperm" portion within any given particle binding composition may come from a single source or from multiple sources. Animal protein can also be mixed with a carbohydrate (and also a protein, if desired) from a plant source in order to yield a synthetic endosperm.

[0011] The iron compound is believed to promote an electrochemical reaction that assists in the formation of a silicate crystal matrix when the particle binding composition is applied to soil. Examples of iron compounds that may be used in the

particle binding compositions of the invention include, but are not limited to, ferric oxide and ferrous oxide.

[0012] The strong base is reacted with the endosperm in the presence of water added in order to ionize the carbohydrate and protein of the endosperm and render them more soluble or dispersible in water. Examples of strong bases that may be used in the particle binding compositions of the invention include, but are not limited to, sodium hydroxide, potassium hydroxide, and mixtures thereof. The use of a strong base results in an intermediate composition that has a strongly alkaline pH.

[0013] The pH adjustor is added to lower the pH and alkalinity of the particle binding composition, which improves its handling ability and renders the composition more compatible with soil. Examples of pH adjustors that may be used in the particle binding compositions of the invention include, but are not limited to, strong acids, such as sulfuric acid, sulfamic acid and nitric acid, and weak acids, such as formic acid, acetic acid and citric acid.

[0014] Optional components such as fibrous materials and/or seeds can be added to promote vegetation or revegetation of denuded soils. Including fibrous materials results in a soil surface that is softer and more compatible with newly germinated seeds and emerging plants. The fibrous material acts to insulate the soil and maintain moisture therein. Nutrients and other adjuvents may be added as desired to yield particle binding compositions having desired properties.

[0015] These and other advantages and features of the present invention will become more fully apparent from the following description and appended claims, or may be learned by the practice of the invention as set forth hereinafter.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

I. INTRODUCTION AND DEFINITIONS

[0016] The present invention relates to particle binding compositions and methods for treating soil and other particles using such compositions. Such compositions effectively bind soil particles together in order to prevent erosion of the soil by wind, water and other environmental forces. Such compositions can, in some cases, be used to bind and stabilize other particles found on or in the vicinity of soil, or which may exist independently of soil, examples of which include ash (*e.g.*, from forest or brush fires), powders resulting from the grinding of rock or other industrial or building operations, particulates emitted by manufacturing processes (*e.g.*, fly ash, cement or silica), and overburden and tailings from mining operations.

[0017] Compositions of the invention are believed to operate at a nano level when binding particles together. Without being bound to any particular theory as to how the particle binding compositions according to the invention actually work to bind soil and other particles together, it is believed that the inventive compositions, when applied to soil, create ionic charges through an electrochemical reaction which pull together silicate particles naturally found in soil so as to form a silicate crystal matrix comprising silicate particles (nano-, micro- and macro-silicate particles) and one or more constituents within the inventive compositions. This matrix causes molecular binding of the soil or other particles. The matrix appears to have the capability of re-actuating multiple times through rehydration of the soil and particle binding composition already applied thereto.

[0018] The recurring actuations of the silicate crystal matrix create a mechanical particle and soil binder that is able to stabilize soil and other particles. For example, the

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compositions are useful in creating a binding matrix to stabilize ash (or ash and soil) in a post-fire environment. They help prevent or inhibit wind and water erosion. Compositions according to the invention can be formulated so as to assist in moisture retention. In some embodiments they can aid in enhanced seed germination and plant growth through the dual action of soil stabilization and moisture retention.

[0019] The terms "solid component" and "solid components" shall refer to any component that is, or that is capable of being, in a solid state at room temperature prior to being mixed with water. The terms "solid component" and "solid components" shall collectively refer to any component within a particle binding composition that is in a solid state, that is in a dissolved state, that is in the form of a colloid or colloidal dispersion, that is in the form of a suspension, or that is or can be otherwise dissolved, dispersed, suspended, or otherwise mixed with water as part of a particle binding composition.

[0020] Prior to being mixed with water, the "solid components" and any other components other than water may be referred to as a "precursor composition". One or more portions or subsets of the "precursor composition" can be dry-mixed and/or mixed with water prior to adding the remaining portions or subsets of the "starting composition" in order to form an "intermediate composition".

[0021] The "weight" of a "solid component" shall be understood as the weight of the component exclusive of any added water, but including any "bound water" that is naturally or normally associated with that component. The term "bound water" shall be given its ordinary meaning, and typically refers to water that is difficult to remove without extreme or special drying procedures.

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II. PARTICLE BINDING COMPOSITIONS

[0022] The particle binding compositions according to the invention include various components that work together to bind soil or other particles together. Without being bound by any particular theory, it is believed that one or more components within the particle binding compositions promote the aforementioned electrochemical reaction that attracts small particles together so as to form a particle binding matrix (*e.g.*, a silicate crystal matrix. The particle binding matrix acts to bind and stabilize soil particles together.

[0023] The particle binding compositions according to the invention are aqueous compositions that comprise water, an endosperm, an iron compound, a strong base, and a pH adjustor. The endosperm, iron compound, strong base, and pH adjustor comprise "non-water constituents" and may exist in non-aqueous form in one or more parts prior to being mixed with water to form a particle binding composition according to the invention. The endosperm, iron compound and strong base are typically solid prior to being added to water and collectively comprise "solid components". The pH adjuster is typically in the form of an aqueous acid, although it can also initially be in solid form.

[0024] After being mixed with water, the non-water constituents may be in the form of a solution, a colloidal dispersion, a suspension, or a combination thereof (*e.g.*, one or more of the non-water constituents may form an aqueous solution, while one or more components may form a colloidal dispersion and/or suspension within the aqueous solution). The total amount of initially solid components added to water to form the particle binding composition will typically vary the specific gravity of the mixture at 25° C. within a range of about 1.01 to about 1.75, preferably within a range of about

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1.015 to about 1.5. Varying the ratio of water and solid components also affects the viscosity of the composition.

A. Endosperm

[0025] The constituent within the particle binding compositions of the invention that is the binder primarily responsible for binding soil and other particles together is the endosperm. The term "endosperm" is commonly understood as the carbohydrate and protein portion of grains and other seeds. In some embodiments, the source of endosperm used to form particle binding compositions according to the invention may comprise a pure or substantially pure endosperm fraction of a grain or other seed (*e.g.*, a grain from which the husk, bran and germ have been removed). In other embodiments, the endosperm may be provided in a non-purified or less purified form in combination with other constituents of the grain or other seed that provides the source of endosperm.

[0026] In yet other embodiments, the carbohydrate and protein constituents of the "endosperm" may be provided or extracted from one or more different types of grain, seeds, or other plant sources (*e.g.*, tubers). For example, some or all of the carbohydrate can be provided from one source (*e.g.*, corn, wheat, or potato starch) and some or all of the protein can be provided by another source (*e.g.* corn, wheat, or even animal protein). As such, the "endosperm" need not contain a carbohydrate and protein in a ratio corresponding to any one particularly grain, seed or other plant source. Nor must the carbohydrate and protein come from any particular source so long as both are present in the particle binding composition. In other words, the term "endosperm", as used in the present application and appended claims, unless otherwise specified, shall include both natural and synthetic "endosperms" comprising (1) at least one type of carbohydrate

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and/or having at least one carbohydrate source, be it grain, other seeds, tubers, or other plant sources, and (2) at least one type of protein and/or having at least one protein source, be it grain, other seeds, tubers, other plant sources, or even animal sources.

[0027] Examples of endosperm sources include grains, examples of which include wheat, rice, corn, oats, barley, rye, sorghum, millet, other cereal grains, soy beans, pinto beans, black beans, other legumes, sesame seeds, other seeds, tubers, examples of which include potatoes and arrowroot, and other plant sources. Although not ordinarily understood to be a source of endosperm, animal protein can be blended with one or more types of plant-derived carbohydrate and, optionally, one or more types of plant-derived protein, to form a synthetic "endosperm" within the scope of the invention. A currently preferred source of endosperm is wheat flour (whole or bleached, edible or non-food grade).

[0028] The endosperm is preferably included in an amount in a range of about 25% to about 95% by weight of the solid components (exclusive of added water) within particle binding or precursor compositions according to the invention, more preferably in a range of about 50% to about 85% by weight of the solid components, and most preferably in a range of about 60% to about 75% by weight of solid components.

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B. Iron Compound

[0029] Without being bound by any particular theory, it is believed that the iron compound is the constituent within the particle binding compositions of the invention that causes, promotes, or is at least involved in what is believed to be an electro-chemical reaction that occurs at a nano level in water in order to form, or promote the formation of, a particle binding matrix (*e.g.*, a silicate crystal matrix). More

particularly, it is believed that the iron ions (Fe^{+2} and/or Fe^{+3}) within the iron compound cause, promote, or are at least partially involved in an electrochemical reaction in water between the particle binding compositions according to the invention and silicate or other particles within the soil, or non-soil particles, that promotes the formation of a particle binding matrix. Empirical observations suggest that the particle binding matrix (*e.g.*, silicate crystal matrix) can be re-actuated multiple times upon rewetting or rehydration of the soil or particles to which particle binding compositions according to the invention have been applied.

[0030] Iron compounds are typically colored, especially at an elevated pH at which many iron compounds are converted to iron oxide in the present of water. As such, another purpose of the iron compound is to act as a dye or pigment within the particle binding compositions of the invention. In the absence of the iron compound (or other dye or pigment), the particle binding composition is typically clear or white. Iron oxide is able to impart a rusty (*e.g.*, red, orange, or yellow) hue, depending on the concentration and/or oxidation state of the iron ions. In some cases, the iron compound can act as a color marker in order to show where and/or how heavy the particle binding composition has been applied. In other cases, the iron compound may causes the particle binding composition to have a more natural hue or tone relative to the soil to which it is applied (*e.g.*, where the particle binding composition would otherwise be white and the soil to be treated is not white).

[0031] Examples of iron compounds that may be used to form particle binding compositions within the scope of the invention include, but are not limited to, iron oxide (*e.g.*, ferrous oxide, ferric oxide, or mixtures or alloys thereof), iron halides (*e.g.*, ferric chloride), iron hydroxide, iron sulfates (*e.g.*, ferric sulfate, ferric subsulfate, ferrous

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sulfate), and iron nitrates. The iron compound may be formed *in situ* through a reaction between an iron source (*e.g.*, reduced iron metal powder) and one or more constituents within the particle binding composition (*e.g.*, water, entrained or available oxygen, hydroxide ion, etc.). A currently preferred iron compound is ferric oxide (Fe_2O_3).

[0032] The iron compound is preferably included in an amount in a range of about 0.01% to about 5% by weight of by weight of the solid components (exclusive of added water) within particle binding or precursor compositions according to the invention, more preferably in a range of about 0.1% to about 1% by weight of the solid components, and most preferably in a range of about 0.25% to about 0.5% by weight of solid components.

C. <u>Strong Base</u>

[0033] It is believed that at least one purpose or function of the strong base is to cause or allow the ionization of the endosperm when the strong base and endosperm are mixed with water. In one aspect, ionization of the endosperm allows or causes it to be more thoroughly dissolved or dispersed within the water used to form the particle binding composition. In another aspect, and without being bound to any particular theory, ionization of the endosperm is believed to cause or allow the endosperm to participate in the electro-chemical reaction between the particle binding composition and silicate or other particles within soil in order to form the particle binding matrix (*e.g.*, silicate crystal matrix).

[0034] The strong base may, in some cases, also cause or promote hydrolysis of the carbohydrate and/or protein in the presence of water depending on the mixing conditions, including the amount of time between the addition of the strong base and the

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pH adjustor. In general, increasing the mixing time before adding the pH adjustor and/the or vigorousness of the mixing process tends to increase the tendency of the carbohydrate and/or protein to become hydrolyzed. Hydrolyzing at least some of the carbohydrate and/or protein may alter the viscosity of the particle binding composition and/or the reactivity and ability to bind of the endosperm with silicates or other particles within the soil.

[0035] Examples of strong bases that may be used to form particle binding compositions according to the invention include alkali metal oxides (*e.g.*, sodium oxide and potassium oxide), alkali metal hydroxides (*e.g.*, sodium hydroxide and potassium hydroxide), alkaline earth metal oxides (*e.g.*, calcium oxide), alkaline earth metal hydroxides (*e.g.*, calcium hydroxide), ammonium hydroxide (*i.e.*, aqueous ammonia), and alkali metal carbonates (*e.g.*, sodium carbonate and potassium carbonate). Currently preferred strong bases include sodium hydroxide, potassium hydroxide, and mixtures thereof.

[0036] The strong base is added in an amount in order to raise the pH to above 13, typically at or above 13.2. As such, the strong base is preferably included in an amount in a range of about 5% to about 75% by weight of by weight of the solid components (exclusive of added water) within particle binding or precursor compositions according to the invention, more preferably in a range of about 15% to about 50% by weight of the solid components, and most preferably in a range of about 25% to about 40% by weight of solid components.

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D. pH Adjustor

[0037] A pH adjustor is added in order to adjust the pH to make the particle binding compositions according to the invention safer for handling and/or more pH balanced relative to soil or other particles to which it is applied. Providing compositions that are pH balanced makes them more compatible with microorganisms found within the soil, and optionally with seeds or other revegetation-promoting materials.

[0038] Because the purpose of the pH adjustor is to lower the otherwise high pH caused by the addition of the strong base, the pH adjustor will typically be an acid or acid buffer that is able to lower the pH of the particle binding composition. In one embodiment, it may be advantageous to add the pH adjustor after adding the strong base in order to allow the strong base to react with and ionize (and optionally hydrolyze) the endosperm to a desired extent prior to adding the pH adjustor. In such cases, the composition that is formed prior to adding the pH adjustor to yield a particle binding composition according to the invention may be considered to be an "intermediate composition".

[0039] The pH adjustor can be any strong or weak acid, including mineral acids, organic acids, acid buffer salts, and the like. Examples of useful mineral acids that may be used as the pH adjustor include, but are not limited to, sulfuric acid, sulfamic acid, hydrochloric acid, nitric acid, and phosphoric acid. Examples, of useful organic acids that may be used as the pH adjustor include, but are not limited to, carbonic acid (*i.e.*, carbon dioxide dissolved in water), formic acid, acetic acid, propanoic acid, benzoic acid, oxalic acid, glycolic acid, citric acid, and ascorbic acid. Examples of useful acid buffer salts include bisulfates, metal chlorides (*e.g.*, aluminum chloride), and other conjugate salts of strong acids and weak bases. A currently preferred pH adjustor is

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sulfuric acid. Another is sulfamic acid. Another is citric acid. All three are compatible with soil.

[0040] The amount of pH adjustor that is added to the intermediate composition to yield a particle binding composition according to the invention will depend on the strength of the pH adjustor relative to the pH of the intermediate composition prior to adding the pH adjustor, as well as the desired pH of the particle binding composition. For example, strong acids such as sulfuric and nitric acid will have a greater pH adjusting (*i.e.*, lowering) affect than weak acids or acid buffer salts. More than one pH adjustor may be used if desired.

[0041] The pH adjustor will preferably be included so as to result in a particle binding composition having a pH in a range of about 10 to about 13, more preferably so as to have a pH in a range of about 10.5 to about 12.8, and most preferably so as to have a pH in a range of about 11 to about 12.6.

E. <u>Water</u>

[0042] Water is added in order to activate the various components within the particle binding composition and also to provide a vehicle that allows the components within the composition to be applied to soil or other particles. In one aspect, water causes or allows the strong base to react with and ionize the endosperm. In another aspect, water causes the strong base and pH adjustor to react in order to reach a desired pH equilibrium. Water may be responsible for causing or allowing one or more constituents within the particle binding composition to carry out the electrochemical reaction with silicate particles within the soil in order to create the silicate crystal matrix.

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[0043] The amount of water that is included within the particle binding compositions according to the invention may be varied as desired to yield compositions having desired properties and concentrations of the components dissolved or dispersed therein. The amount of water relative to the initially solid components affects the viscosity and particle-binding ability of the final aqueous particle binding composition. Increasing the solids content generally increases the viscosity and binding ability of the composition.

[0044] In some embodiments, the desired amount of water within the final particle binding composition is added all at once. In other embodiments, particle binding compositions according to the invention may be produced in concentrated form using a first quantity of water and then diluted prior to use using a second quantity of water. The water can be fresh or brackish. It may comprise non-potable water suitable for irrigation.

[0045] The water within particle binding compositions according to the invention will preferably be included in an amount in a range of about 60% to about 99.9% by weight of the aqueous particle binding composition, more preferably in a range of about 75% to about 99.5% by weight of the aqueous particle binding composition, and most preferably in a range of about 90% to about 99% by weight of the aqueous particle binding composition.

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F. Optional Components

[0046] The particle binding compositions according to the invention may optionally include other components as desired to yield compositions having desired properties. Examples of optional components that may be added include, but are not limited to,

pigments, dyes, soil nutrients, fertilizers (*e.g.*, chemical and organic), auxiliary binders (*e.g.*, synthetic polymers, clay, and hydraulic cement), wetting agents, surfactants (*e.g.*, salts of fatty acids, sulfonates, and organic sulfates), humectants (*e.g.*, ethylene glycol, polyethylene glycol, propylene glycol, polypropylene glycol, other glycerin, or other polyols).

[0047] In the case where the particle binding composition is intended to be assist in the vegetation or revegetation of soil (*e.g.*, in the case where soil has been denuded by fire or newly graded using earth moving equipment), it may be desirable to include a fibrous component in order to soften and enrich the soil so as to create a more fertile and friendly environment for the planting of vegetation and/or the emergence of newly sprouted seeds. The fibrous component may also control drift caused by air turbulence in aerial applications, and it insulates and maintains moisture within the soil. Examples of fibrous components that may optionally be added to particle binding compositions according to the invention include wood and plant fibers, polymeric fibers, mineral fibers, wood chips, saw dust, and recycled paper. In one embodiment, the fibrous component may include a mixture of thermally processed wood fibers and recycled newsprint.

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[0048] In addition, the strong base, iron oxide and endosperm may, in some cases, promote the chemical breakdown of the fibrous material, particularly cellulose and wood fiber materials. This creates an increased solid suspension in the liquid matrix. A homogeneous-like suspension created by the aqueous mixture of endosperm, iron oxide and strong base reduces solids separation that may otherwise be caused by the gravitational differences of weight when the particle binding composition is dropped from an aircraft during aerial application.

[0049] When included, the fibrous component will preferably be included in an amount in a range of about 0.1% to about 25% by weight of the water within the aqueous particle binding composition, more preferably in a range of about 1% to about 10% by weight of the water within the aqueous particle binding composition, and most preferably in a range of about 2.5% to about 5% by weight of the water within the aqueous particle binding composition.

[0050] In order to promote faster vegetation or revegetation of denuded soil, one or more types of seeds may be included within particle binding compositions according to the invention, preferably in combination with a fibrous component as discussed above. In order to promote a natural looking environment, a mixture of seeds for plants native to a particular region or tract of land being treated may be added to the particle binding composition.

III. METHODS OF MAKING PARTICLE BINDING COMPOSITIONS

[0051] The various components within the particle binding compositions of the present invention can be blended in any desired manner in order to yield compositions having desired properties. In one currently preferred method of mixing together the components, the endosperm and iron compound are initially dry mixed together in the form of dry powders or particulates using a shear-type mixer. Creating a well-mixed dry mixture of endosperm and the iron compound is believed to assist in the electrochemical reaction(s) discussed herein and accelerate the reaction between the endosperm and strong base. In many cases, the extent of mixing can be monitored by observing the extent to which the iron compound has colored or stained the endosperm. The typical duration for the initial dry mixing step is about 3-5 minutes.

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[0052] After the endosperm and iron compound have been dry mixed together, a container or vessel is filled with a desired quantity of fresh or brackish water. Because the particle binding composition is intended for application to soil, it is generally not necessary for the water to be sterile or potable. For example, non-potable water suitable for irrigation can be employed. The dry mixture of endosperm and iron oxide is added to the vessel and mixed to form a substantially uniform suspension of endosperm and the iron compound within the water. The duration of this mixing step is typically about 3-5 minutes using aggressive agitation.

[0053] While continuing to agitate the suspension, the strong base is added to the mixture, which is stirred for about 3-5 minutes in order for the reaction between the endosperm and strong base to occur. This yields an intermediate composition having a pH of about 13.2 or more. Thereafter, the pH adjustor is added and stirred into the intermediate composition for about 3-5 minutes to adjust the pH of the particle binding composition to a desired pH or within a desired pH range.

[0054] The particle binding composition so formed can be used as desired to bind soil or other particles together. Alternatively, a composition more suitable for promoting vegetation or revegetation of denuded soil can be prepared by adding a fibrous material to the particle binding composition and mixing for about 1-10 minutes. In some embodiments, one or more types of seeds may also be added in order to yield a composition that more quickly results in the emergence of plant life from the treated soil. In order to better reflect the natural flora of a particular tract of land, seeds of plants that are native to the area may be advantageously selected and added to the particle binding composition.

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IV. METHODS OF USING PARTICLE BINDING COMPOSITIONS

[0055] The particle binding compositions according to the invention may be applied to soil or other particles in any manner known in the art. For example, the particle binding compositions may be applied to the soil surface by means of industry standardized hydraulic pumping equipment or through aerial dispersing (*e.g.*, especially by rotor wing or fixed wing aircraft).

[0056] Aerial spraying or broadcasting is suitable when applying a particle binding composition to large areas and/or steep terrain. In the case of dirt roads or trails, the particle binding composition can be applied by hydraulic spraying equipment, such as water trucks and manually or mechanically held nozzles.

[0057] When the aqueous particle binding composition is applied to soil it is further buffered by the natural mineral components found naturally within the soil, typically to a more neutral pH of about 9-10. A reduction in pH to a more neutral pH assists in the survival of soil bacteria, fungi and assists in the initial breakdown of many organic materials used in the bacteriological soil food chain.

[0058] The particle binding compositions according to the invention will typically dehydrate as a result of the natural evaporation process of soil and rehydrate as a result of natural precipitation or the application of water by irrigation. Rewetting of the particle binding composition causes the composition to be re-actuated in order to rebind particles that may have been dislodged or separated from the binding matrix over time.

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V. EXAMPLES OF THE PREFERRED EMBODIMENTS

[0059] The following examples are provided in order to illustrate particle binding compositions according to the invention. It should be understood that the following

examples are given by way of example only, and should not be understood as in any way limiting the scope of the invention.

EXAMPLE 1

[0060] Aqueous particle binding compositions were manufactured by mixing together the following components:

Endosperm (wheat flour)	100 lbs.
Iron oxide (Fe_2O_3)	0.5 lb.
Sodium Hydroxide	25 lbs.
Potassium Hydroxide	25 lbs.
Water	8340 lbs. (1000 gallons)
Sulfuric Acid	variable

[0061] The endosperm and iron oxide were dry-mixed together for 3-5 minutes using a shear-type mixer in order to ensure more even dispersion of the iron oxide in the final composition. Associating the iron oxide with the endosperm was believed to assist in causing or promoting an electrochemical reaction between the particle binding composition and silicate particles within soil to which the composition is applied. Thereafter, the endosperm and iron oxide mixture was added to a vessel containing the water (either fresh or brackish water) and mixed for 3-5 minutes using strong agitation in order to form a suspension of endosperm and iron oxide within the water.

[0062] Thereafter, the sodium hydroxide and potassium hydroxide were added to and mixed with the suspension for 3-5 minutes in order to react with and ionize the

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endosperm. It is believed that the iron oxide also reacted or associated with the endosperm as a result of the water and hydroxide constituents. The intermediate composition formed thereby had a pH of about 13.2 or higher.

[0063] After mixing and reacting the sodium hydroxide and potassium hydroxide with the endosperm for a desired period of time, sufficient sulfuric acid was added to the intermediate composition and mixed for 3-5 minutes in order to yield a final pH-adjusted particle binding composition having a pH in a range of about 10-12. The non-aqueous components exclusive of the added water had a combined concentration of about 1.8% by weight of the water.

EXAMPLE 2

[0064] Soil binding compositions suitable for vegetation or revegetation of denuded soil were made by adding 250-375 lbs. of a fibrous material to the particle binding composition made according to Example 1. The fibrous material comprised a mixture of 40% thermally treated wood fibers and 60% recycled newsprint.

EXAMPLE 3

[0065] Aqueous particle binding compositions were manufactured by mixing together the following components:

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Endosperm (wheat flour)	133.5 lbs.
Iron oxide (Fe_2O_3)	0.67 lb.
Sodium Hydroxide	34 lbs.
Potassium Hydroxide	34 lbs.
Water	8340 lbs. (1000 gallons)
Sulfuric Acid	variable

[0066] The endosperm and iron oxide were dry-mixed together for 3-5 minutes using a shear-type mixer in order to ensure more even dispersion of the iron oxide in the final composition. Thereafter, the endosperm and iron oxide mixture was added to a vessel containing the water (either fresh or brackish water) and mixed for 3-5 minutes using strong agitation in order to form a suspension of endosperm and iron oxide within the water.

[0067] Thereafter, the sodium hydroxide and potassium hydroxide were added to and mixed with the suspension for 3-5 minutes in order to react with and ionize the endosperm. The iron oxide may have also reacted or associated with the endosperm as a result of the water and hydroxide constituents. The intermediate composition formed thereby had a pH of about 13.2 or higher.

[0068] After mixing and reacting the sodium hydroxide and potassium hydroxide with the endosperm for a desired period of time, sufficient sulfuric acid was added to and mixed with the intermediate composition for 3-5 minutes in order to yield a final pH-adjusted particle binding composition having a pH in a range of about 10-12. The non-aqueous components exclusive of the added water had a combined concentration of about 2.4% by weight of the water.

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EXAMPLE 4

[0069] Soil binding compositions suitable for vegetation or revegetation of denuded soil were made by adding 250-375 lbs. of a fibrous material to the particle binding composition made according to Example 3. The fibrous material comprised a mixture of 40% thermally treated wood fibers and 60% recycled newsprint.

EXAMPLE 5

[0070] Aqueous particle binding compositions were manufactured by mixing together the following components:

Endosperm (wheat flour)	150 lbs.
Iron oxide (Fe_2O_3)	0.75 lb.
Sodium Hydroxide	38 lbs.
Potassium Hydroxide	38 lbs.
Water	8340 lbs. (1000 gallons)
Sulfuric Acid	variable

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[0071] The endosperm and iron oxide were dry-mixed together for 3-5 minutes using a shear-type mixer in order to ensure more even dispersion of the iron oxide in the final composition. Thereafter, the endosperm and iron oxide mixture was added to a vessel containing the water (either fresh or brackish water) and mixed for 3-5 minutes using strong agitation in order to form a suspension of endosperm and iron oxide within the water.

[0072] Thereafter, the sodium hydroxide and potassium hydroxide were added to and mixed with the suspension for 3-5 minutes in order to react with and ionize the endosperm. The iron oxide may have also reacted or associated with the endosperm as a result of the water and hydroxide constituents. The intermediate composition formed thereby had a pH of about 13.2 or higher.

[0073] After mixing and reacting the sodium hydroxide and potassium hydroxide with the endosperm for a desired period of time, sufficient sulfuric acid was added to the intermediate composition and mixed for 3-5 minutes in order to yield a final pH-adjusted particle binding composition having a pH in a range of about 10-12. The non-aqueous components exclusive of the added water had a combined concentration of about 2.7% by weight of the water.

EXAMPLE 6

[0074] Soil binding compositions suitable for vegetation or revegetation of denuded soil were made by adding 250-375 lbs. of a fibrous material to the particle binding composition made according to Example 5. The fibrous material comprised a mixture of 40% thermally treated wood fibers and 60% recycled newsprint.

EXAMPLE 7

[0075] Aqueous particle binding compositions were manufactured by mixing together the following components:

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Endosperm (wheat flour)	66 lbs.
Iron oxide (Fe_2O_3)	0.38 lb.
Sodium Hydroxide	33 lbs.
Water	8340 lbs. (1000 gallons)

[0076] The endosperm and iron oxide were dry-mixed together for 3-5 minutes using a shear-type mixer in order to ensure more even dispersion of the iron oxide in the final composition. Thereafter, the endosperm and iron oxide mixture was added to a vessel containing the water (either fresh or brackish water) and mixed for 3-5 minutes using strong agitation in order to form a suspension of endosperm and iron oxide within the water.

[0077] Thereafter, the sodium hydroxide and potassium hydroxide were added to and mixed with the suspension for 3-5 minutes in order to react with and ionize the endosperm. The iron oxide may have also reacted or associated with the endosperm as a result of the water and hydroxide constituents. The particle binding composition formed thereby had a pH of about 13.2 or higher. The non-aqueous components exclusive of the added water had a combined concentration of about 1.2% by weight of the water.

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EXAMPLE 8

[0078] Sulfuric acid is added to the particle binding composition of Example 7 in an amount so as to yield a pH-adjusted particle binding composition having a pH in a range of about 10-12.

EXAMPLE 9

[0079] Aqueous particle binding compositions were manufactured by mixing together the following components:

Endosperm (wheat flour)	150 lbs.
Iron oxide (Fe_2O_3)	0.75 lb.
Sodium Hydroxide	75 lbs.
Water	8340 lbs. (1000 gallons)

[0080] The endosperm and iron oxide were dry-mixed together for 3-5 minutes using a shear-type mixer in order to ensure more even dispersion of the iron oxide in the final composition. Thereafter, the endosperm and iron oxide mixture was added to a vessel containing the water (either fresh or brackish water) and mixed for 3-5 minutes using strong agitation in order to form a suspension of endosperm and iron oxide within the water.

[0081] Thereafter, the sodium hydroxide and potassium hydroxide were added to and mixed with the suspension for 3-5 minutes in order to react with and ionize the endosperm. The iron oxide may have also reacted or associated with the endosperm as a result of the water and hydroxide constituents. The particle binding composition formed thereby had a pH of about 13.2 or higher. The non-aqueous components exclusive of the added water had a combined concentration of about 2.6% by weight of the water.

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EXAMPLE 10

[0082] Sulfuric acid is added to the particle binding composition of Example 9 in an amount so as to yield a pH-adjusted particle binding composition having a pH in a range of about 10-12.

[0083] The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

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